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# Acidization of Alalcime-Cemented Sandstone, Gulf of Mexico

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## ABSTRACT

In a number of offshore Louisiana oil wells a white powdery, finely granular siliceous material was swabbed from wells and found on screens after acidizing with mud acid. The white material was analyzed as silica gel or aluminosilicate gels. Analysis of the formation sands which produced the white material after acidization shows the sands to be extensively cemented with analcime.

Analcime is a hydrated sodium aluminosilicate related to zeolites. Analcime is a low density (2.3 gm/cc) mineral which is highly soluble in HF and will form hydrated gels with concentrated HCl. Analcime is associated with volcanic ashes, altered volcanic sandstones and salt domes. There are many salt dome related oil fields in the central Gulf where volcanic ash beds are locally common. Therefore, the occurrence of analcime cemented sandstones may be more widespread in the Gulf than previously suspected.

A significant production decline was noted in a number of wells in the South Pass Blk. 61 field, a complex salt dome related structure, after acidization with HF or concentrated HCl. In many cases, production decline is attributed to damage by mineral precipitation or gel formation from acid spent on analcime-cemented sands.

References and illustrations at end of paper.

This paper describes the petrographic and fluid/rock studies done to optimize pre and/or post gravel pack acid stimulation system for analcime-cemented sandstones from South Pass Blk. 61. SEM photos show the effect of various acid systems on analcime and an effective acid system for these types of formations is discussed.

## INTRODUCTION

The discovery of the common occurrence of the zeolite mineral analcime as a sandstone cement at South Pass Blk. 61 has contributed to an overhaul of standard completion and stimulation procedures in the field. Analcime is a low-density, hydrated mineral with a high solubility in HF and a strong tendency to form hydrated gels in concentrated HCl (1). These properties create a serious potential for premature spending of acids and formation of silicate gels or scale which can potentially damage the near-wellbore region. This paper is a summary of the nature and distribution of analcime cement in the field and of the interaction of analcime with various acids. The significance of acid selection to the prevention of formation damage in analcime cemented sandstones is illustrated by selected case histories.

## GENERAL RESERVOIR DESCRIPTION

The South Pass Blk. 61 Field is a salt dome-related structure (See Figure 1). The field is structurally complex, with many faults of varying magnitude and orientation, multiple reservoir

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sands and oil/water contacts, relatively steep dips and variations in quality within and between reservoirs due to facies changes or localized cementation. Reservoir character ranges from massive, blocky sands with excellent lateral continuity to thick intervals of shaley laminated sand. Completion procedures during early field development which were geared towards the best quality sands included sand control practices.

The typical reservoir is a poorly consolidated, very fine to fine-grained sand. Deeper and/or older reservoirs, or those in close proximity to the salt dome (See Figure 1) are poorly cemented. Common cementing minerals include calcite, pyrite, analcime, quartz, and halite (salt). Clay content is the most important mineralogical influence on reservoir quality. Most of the sands fall into one of three (3) rock types: clean sand (with and without cement), thinly laminated sand, and shaley sand with extensive clay matrix. Recognition of the variety of sand textures and quality requires an integrated appraisal involving mudlogs, openhole wireline logs, petrographic analysis of cuttings and cores, and experience in the field. The lessons learned during completion of wells with high-quality reservoirs could not be directly transferred to more marginal or complex zones because of differences in sand strength and sensitivity to wellbore fluids. The mineral cement analcime is of particular interest here because its presence was not suspected before the integrated application of formation evaluation, the mineral is difficult to detect from wireline logs and it is very fluid-sensitive.

#### ANALCIME

Analcime is a hydrated sodium aluminosilicate,  $\text{NaAlSi}_2\text{O}_6\text{H}_2\text{O}$ , generally classified with the zeolite family of minerals. It occurs as a primary mineral in some silica-poor volcanic rocks and as a secondary cement and alteration mineral within vugs in basaltic volcanics, in tuffaceous deposits, and in volcanic-rich sandstones (2,3). Analcime is thermally stable (note its occurrence as a primary volcanic phase), but in sandstone with zeolite cement analcime is an intermediate step in burial diagenesis. Analcime is a low density phase (2.3 g/cc), with a significant water content (8% wt/wt). Analcime is soluble in HF and readily converted into a hydrous aluminosilicate gel in strong HCl or by a highly alkaline fluid (i.e., mud filtrates with pH > 12).

As a sandstone cement at South Pass Blk. 61, analcime occurs as a pore-filling phase in amounts ranging from trace to 20 wt%, and is commonly associated with framboidal pyrite. Analcime cement is largely confined to sandstones buried deeper than 7000', and can form in clean sand beds of any thickness (down to millimeter-scale laminations). Its distribution is typically patchy on a similarly-small scale: one effect of acidization on such sandstones is the possible scavenging and concentration of analcime components into a distribution with a much lower permeability. Analcime content in pay sands is generally low enough that log porosities are only slightly inflated, but it is high enough to present a serious damage potential during acidization.

#### LAB TESTS

Lab tests (4) were conducted to determine the best acid to stimulate the near wellbore area and the effect of the stimulation fluid on the mineralogy of the formation. The tests included X-ray diffraction analysis to determine mineralogy, thin-section petrography to determine location of the minerals, detailed SEM examinations to determine the effect of acid systems, standard acid solubility tests and analysis of acid solubility supernates.

The composition of the formation of interest is given in Table I. Thin-section (Figure 2) and SEM (Figure 3) photomicrographs show the analcime to be the primary cementing mineral in this interval. A synthetic formation mixture was used in all the acid solubility tests because of the very limited availability of formation material.

Acid solubility tests conducted on pure analcime given in Table II confirm that the mineral is very soluble in HF and moderately soluble in HCl and acetic acid. It was noted that a white pasty gel formed with the analcime and HF or HCl and not with the acetic acid. The results of the acid solubility tests of formation material typical of the South Pass field are summarized in Table III.

As expected from the mineralogy, the mud acid systems dissolved the most and the acetic acid reacted the least. These lab tests show that acetic acid or a combination of acetic and hydrochloric acid provide enough dissolution of formation material to help clean up the perforations and remove acid soluble fluid loss material. The moderate solubility of

the analcime and the lack of a visible gel in acetic acid suggests that this type of acid system will minimize detrimental by-products of such an acid treatment. This is evidenced by the low solubility in acetic acid of the formation containing analcime and the lack of interaction of the acetic acid with the analcime as shown by detailed SEM examination. It was observed that the typical formation material, when mixed with mud acid or HCl, was very slow to filter during the acid solubility tests and that a white "crusty" material formed on the retained formation material once it was dried. This "crust" was not evident with the acetic acid. This implies the presence of some type of gel development with the mud acid and the HCl systems.

Evidence of the interaction of HCl and acetic acid with the analcime was determined using detailed SEM photos of analcime before and after exposure to acid. The results of the HCl tests shown in Figures 4-5 are SEM photos of analcime before and after exposure to 15% HCl. Figures 6-7 are SEM photos of analcime before and after exposure to 10% acetic acid. The SEM photos show that there is some interaction of the analcime with HCl, but virtually no interaction with the acetic acid. This implies that the acetic acid reacted with only the calcareous material in the formation.

Because of the method of sample preparation and the fluid/solid ratios used, amorphous gel development is not readily apparent in SEM examinations of the formation after exposure to the acid systems. However, the indirect evidence from the acid solubility tests strongly supports the presence of the gel when the formation is exposed to the strong mineral acid. These results along with the acid solubility tests were the basis for selecting acetic acid in the completions of the analcime-rich zones in the field.

#### FIELD RESULTS

Initially, wells in the general proximity of the salt dome incorporated a stimulation treatment using common variations of mud acid in combination with gravel packing. The acid treatment was a standard pre-gravel pack practice used to remove the residual fluid loss material before and during placement of the gravel pack.

Completion practices were changed as a result of the discovery of significant amounts of analcime in the formation and determination of the

interaction of analcime with strong mineral acids. The new completion practice includes the use of 10% acetic acid or a combination of 10% acetic acid and 5% HCl to clean perforation and lost circulation material. The practice of matrix stimulation during the gravel pack operation is no longer done.

Since 1988, over 20 wells drilled and completed near salt domes incorporated the use of acetic acid or a combination of acetic acid and hydrochloric acid in treatments or gravel pack operations. None of the wells have shown scaling tendencies or the presence of the white powdery material. Pressure transient analysis of the wells does not indicate any damage; therefore, no subsequent mud acid treatments were done or planned on the wells. The changes in the completion practices have resulted in substantial savings in treatment costs and rig time. The biggest reward of changing the completion practices is the trouble free production from the wells.

Ongoing petrographic investigations have identified over 30 wells in the field which contain analcime-cemented sandstone. The results of this study and experience in this field have caused ARCO to pay special attention to the mineralogy of formations near salt domes in the Gulf of Mexico, particularly for the presence of analcime cement, if stimulation is planned.

#### CONCLUSIONS

The following conclusions and observations are made based on the laboratory results and experience at South Pass Blk. 61 Field:

1. Analcime will form a gelatinous material upon exposure to strong HCl, or after reprecipitation from spent mud acid.
2. Acetic acid systems provide good stimulation of formations containing calcareous minerals and are compatible with the zeolite mineral, analcime.
3. Small amounts of analcime in a formation can cause major production decreases upon stimulation with strong acid systems.
4. Analcime cements is potentially widespread adjacent to salt domes in otherwise typical reservoir sands offshore Louisiana.

5. Mud acid stimulation treatments are not recommended in fields adjacent to salt domes unless detailed petrographic analysis of the formation for analcime minerals are conducted.

#### ACKNOWLEDGEMENTS

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TABLE I. X-ray Diffraction Analysis

Component	Weight %	
	11.290-320°	11.350-380°
Quartz	30-40	25-30
Feldspar	10-15	5-10
Calcite	2-5	0.5-2
Dolomite	2-5	0
Kaolinite	2-5	5-10
Illite/Mica	5-10	5-10
Smectite	20-30	30-40
Analcime	2-5	2-5
Siderite	5-10	2-5

TABLE II: Acid Solubility of Analcime

Acid System	% Weight Loss
10 % Acetic Acid	42
7.5% HCl	65
15% HCl	71
6:1.5 HCl:HF	91

TABLE III: Formation Acid Solubility Tests

Acid System	% Weight Loss
7.5% HCl	23
10% Acetic Acid	17
6:1.5 HCl:HF	83

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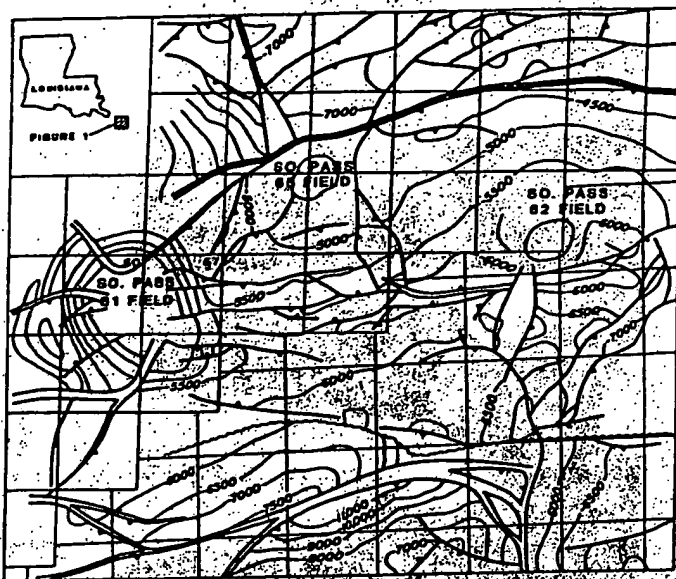


FIGURE 1: LOCATION MAP AND GENERALIZED STRUCTURE, SOUTH PASS BLOCK 61 FIELD



FIGURE 2: THIN SECTION OF ANALCIME-CEMENTED SANDSTONE

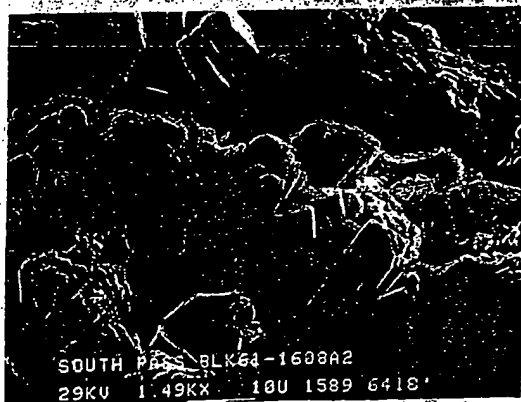
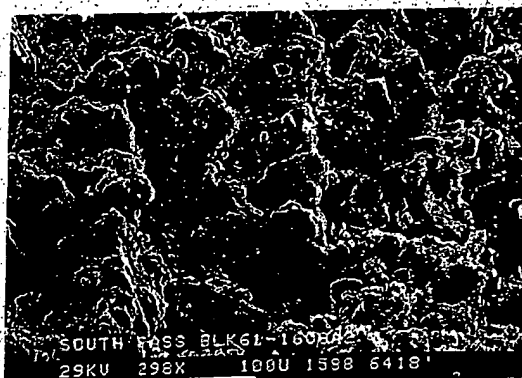


FIGURE 3: SEM PHOTOMICROGRAPHS OF ANALCIME-CEMENTED SANDSTONE

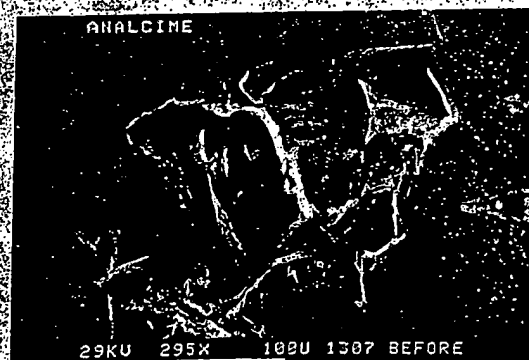


FIGURE 4: ANALCIME BEFORE AND AFTER EXPOSURE TO 15% HCl

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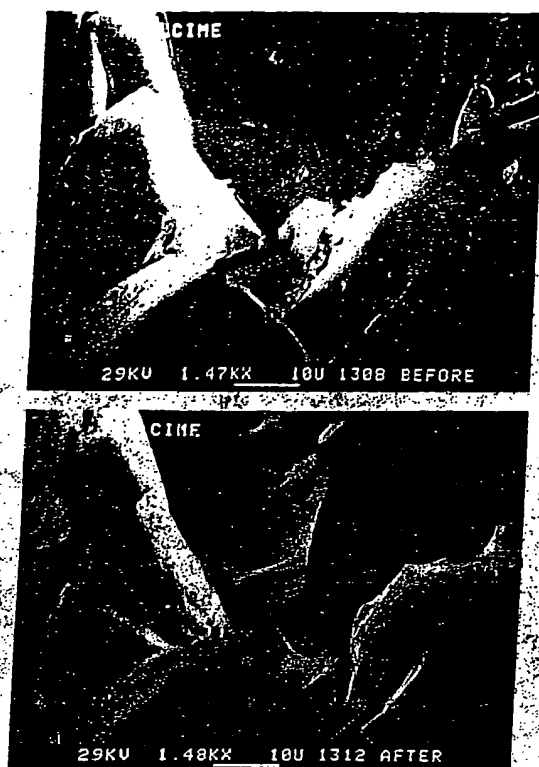


FIGURE 5: ANALCIME BEFORE AND AFTER EXPOSURE TO 15% HCl

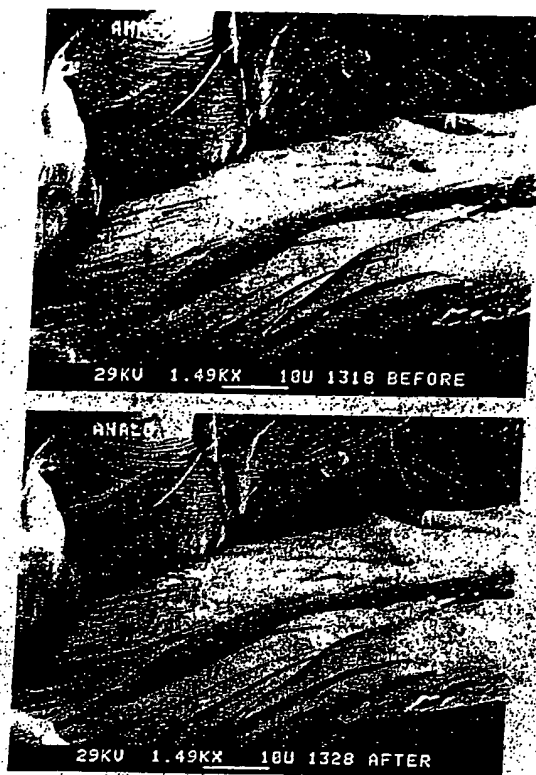


FIGURE 6: ANALCIME BEFORE AND AFTER EXPOSURE TO 10% ACETIC ACID

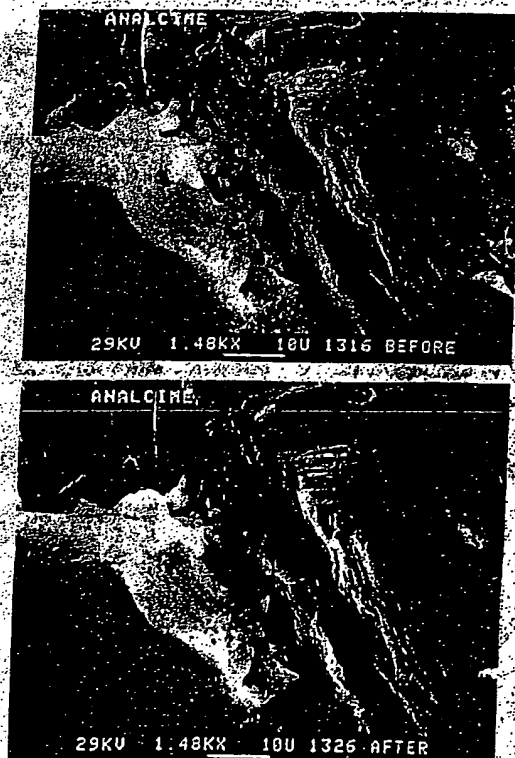


FIGURE 7: ANALCIME BEFORE AND AFTER EXPOSURE TO 10% ACETIC ACID